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(*To be continued in January Number.*)

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ON A QUANTITATIVE RELATION GOVERNING CERTAIN LINGUISTIC PHENOMENA.

Professor Edward Sievers[1] in his paper on "The Relation of German Linguistics to Indo-Germanic Linguistics and German Philology," read before the St. Louis Congress of Arts and Sciences, speaks of word-accent and sentence-accent, and of certain efforts that have been made to solve what he calls the problem of sentence-rhythm and language-melody. He expresses the conviction that authors are unconsciously limited in their choice of expressions; that their writings are characterized by a certain rhythm which is so clear and so well-defined that it becomes an important factor in philological criticism. To use his own words,

"The individual speaker—especially if he be an author, and no matter whether he be writing in verse or prose—is under the ban of certain rhythmic-melodic conceptions, which unconsciously influence his choice of expressions. The influence is so strong that an author's individual production, often even his entire work, assumes a more or less plain, yet easily recognizable characteristic rhythmic-melodic impress. In language melody especially, the personal peculiarity of the individual author becomes an important factor in the separation of unrelated portions of a preserved text. Personal observations conducted along these lines for several years convinced me that there is no phase of philological criticism which may not receive new light from this source, whether we are dealing with the selection of different versions of a text and the accurate determination of linguistic and metrical forms or with the most complicated problems of higher criticism. The method to be employed in the investigation and application of the individual rhythmic-melodic standards are difficult indeed and have been determined only in small measure. Years will no doubt pass by before empirical proof of the validity of this thesis can be established in detail. Yet even this day we may express the fond hope that the evidence will be forthcoming."

In view of these remarks, I wish to call attention to a number of investigations which anticipated Professor Sievers' hypothesis, and furnish in no small measure "empirical proof of the validity" of his thesis. Furthermore I wish to communicate the discovery of a quantitative relation, the first of its kind ever observed, and which, it would seem, points the way to, if it does not constitute the beginning of, a new branch of linguistic science.

As to the work done in anticipation of Professor Sievers' thesis, Professor Sherman,[2] Mr. Gerwig[3]

[1] Congress of Arts and Sciences, Universal Exposition, St. Louis, 1904, vol. 3: 284.

[2] *Some Observations upon the Sentence-Length in English Prose*, University (of Nebraska) Studies, vol. I, p. 119.
On Certain Facts and Principles in the Development of Form in Literature, *Ibid.*, vol. I, p. 337.

[3] *On the Decrease of Predication and of Sentence Weight in English Prose*, *Ibid.*, vol. II, p. 17.

and others investigated in great detail certain so-called sentence-constants, as sentence length—the average number of words per sentence used by an author, predication-average or the average number of finite verbs per sentence, simple-sentence-frequency—the average number of simple sentences per hundred, etc. The results of Sherman and Gerwig seemed to establish the principle of the invariability of sentence-constants for a given author. There is one set and only one set of constants for each author, while different authors employ in general different sets of constants, in short, the results seemed to justify the conclusion that an author's style is characterized by certain ascertainable numerical constants.

In the second place mention must be made of Dr. T. C. Mendenhall's[4] researches on average word-lengths, and his theory of characteristic curves. His results led him to believe that authors not only put a uniform average number of letters into their words, but that in the long run, one letter words, two letter words, three letter words, etc., do recur with constant frequencies. These relative frequencies give rise to a curve which is characteristic of the author. One author can give rise to but one curve, different curves invariably signify different authorship. It was thought that one hundred thousand words would be both necessary and sufficient to furnish such a characteristic curve.

The present writer[5] found that one and the same author may employ several distinct sets of sentence-constants, and may give rise to two or more distinct word-curves. Previous investigators had not taken into consideration the effect of the various types of composition, as drama, fiction, biography, criticism, description, science, etc., upon the sentence-constants and word-curves. The principle of invariable sentence-constants as well as the theory of characteristic curves must be modified so as to allow for the form into which an author casts his thought. In fact, an examination and comparison of all the data available clearly point to the conclusion that the form of composition rather than an author's individuality is the controlling factor in the determination of at least sentence-length, predication-average, simple sentence-percentage, and the relative frequencies of words of various lengths.

In all the work done thus far to establish the invariability of sentence-constants, an equally if not more important question can be raised, the question whether there exists any determinate relation among the sentence-constants themselves. Written language considered as an organism should be subject to the law of organisms in general, and have the proportion of its parts governed by the laws of probability. Not only should the component parts of a composition yield themselves to the law of the mean, but their interrelation should be definite and, if sufficiently simple, should admit of determination. It is with this question that the remainder of this paper is to deal.

Mr. Gerwig's tables contain the results by actual count of about 60,000 sentences analysed with respect to predication-averages and simple-sentence-percentages. The results represent seventy-one different English authors and cover every period of English literature from Chaucer to the present day writers. As originally exhibited the arrangement was by authors, but for the present purpose it will be more convenient to arrange the results with reference to one of the constants in question, say the predication-average which we shall denote by P. The corresponding simple-sentence-percentage is denoted by S. The columns headed by W contain the number of sentences on which the respective averages are based. Averages from groups of less than 500 sentences have been omitted.

P = 1.50 — 2.00

1.	W	P	S
Symonds............	500	1.84	58
Macaulay............	500	1.88	48
Average......		1.86	53

[4] "The Characteristic Curves of Composition," *Science*, March 11, 1887.

"Solution of a Literary Problem," *Popular Science Monthly*, Dec., 1901.

[5] "The Sherman Principle in Rhetoric and its Restrictions," *Popular Science Monthly*, vol. 63 (1903), p. 534.

On the Variation, etc., University (of Nebraska) Studies, vol. 3, p. 229.

"On the Significance of Characteristic Curves of Composition," *Popular Science Monthly*, vol. 65 (1904), p. 132.

P = 2.00 — 2.25

2.	W	P	S
Phelps	500	2.03	50
Channing	1000	2.09	42
Bartol	1500	2.10	44
Emerson	500	2.14	38
Macaulay	5000	2.16	36
Blaine	500	2.23	39
Average		2.14	39.1

P = 2.25 — 2.50

3.	W	P	S
Everett	1000	2.27	32
Macaulay	4000	2.29	32
Geikie	500	2.34	32
Grant	500	2.34	31
Emerson	1000	2.38	37
Forum	500	2.42	32
James	500	2.45	24
Phillips	500	2.47	53
Shelley	500	2.48	26
Average		2.34	32.9

P = 2.50 — 2.75

4.	W	P	S
Junius	500	2.54	26
Greeley	500	2.56	26
Disraeli	500	2.57	27
Channing	2000	2.59	31
Shaftesbury	500	2.61	28
Darwin	500	2.64	21
Lowell	1500	2.67	22
Fiske	500	2.69	20
Pater	500	2.74	26
Average		2.62	25.9

P = 2.75 — 3.00

5.	W	P	S
Arnold	500	2.77	20
Shakespeare	500	2.76	31
Hamerton	500	2.85	20
Higginson	500	2.85	21
Thoreau	500	2.86	25
Choate	500	2.88	30
Browning	500	2.91	25
George	500	2.92	23
Munger	500	2.92	26
Goldsmith	500	2.95	18
Newman	500	2.97	16
Average		2.88	23.2

P = 3.00 — 3.25

6.	W	P	S
Stevenson	500	3.01	24
Holland	500	3.03	21
Franklin	500	3.04	19
Mandeville	500	3.08	22
Bacon	500	3.12	19
Carlyle	500	3.12	18
White	500	3.15	15
Johnson	500	3.23	16
Average		3.10	19.2

P = 3.25 — 3.50

7.	W	P	S
Hume	500	3.29	12
Coleridge	500	3.33	19
Huxley	500	3.36	16
Scott	500	3.36	16
Moore	500	3.38	11
Gladstone	500	3.43	16
Ascham	500	3.49	19
Ruskin	500	3.50	18
Average		3.39	15.9

P = 3.50 — 4.00

8.	W	P	S
Lyly	500	3.51	17
Luke	500	3.62	10
Bolingbroke	1000	3.65	14
More	500	3.65	15
Addison	500	3.67	12
Very	500	3.67	11
Swift	500	3.69	13
De Quincey	500	3.69	14
Barrow	500	3.74	20
Howell	500	3.74	11
Wordsworth	500	3.87	17
Bunyan	500	3.91	10
Sidney	500	3.98	10
Average		3.70	13.4

P = 4.00 — 4.50

9.	W	P	S
Steele	500	4.02	10
Hooker	500	4.12	12
Chaucer	1000	4.17	8
Hakluyt	500	4.22	12
Average		4.17	10

P = 4.50 — 5.00

10.	W	P	S
Latimer	500	4.75	13
Milton	500	4.87	6
Dryden	500	4.89	6
Average		4.84	8.3

P = 5.00 — 5.50

11.	W	P	S
Chaucer	500	5.25	4
Spencer	1000	5.44	8
Average		5.38	6.7

The results have been arranged in eleven groups, the first group containing the works for which P lies between 1.50 and 2.00, the second those for which P lies between 2.00 and 2.25, etc. The average for each group is the weighted average, that is the average P is obtained by multiplying each separate P by the number of sentences from which it is taken, after which all the products are added and their sum divided

by the total number of sentences in the group. Similarly the average S's are obtained.

On comparing the individual pairs of corresponding P's and S's, one fact becomes rather evident; namely, while the P's form an ascending series of numbers, the S's form a series which is in the main descending. The exceptions to this rule disappear entirely if, instead of the individual pairs of values, we consider the averages of the various groups. To the larger P there corresponds the smaller S, to the smaller P corresponds the larger S. This signifies a general reciprocal relation between the P's and S's, a relation which we might have expected *a priori*. Other things equal, there will be the largest average number of predications, when the simple sentences are fewest, and vice a versa, when the simple-sentence-percentage is 100; that is, when all sentences are simple, the predications per sentence will be fewest.

At this point the question suggests itself whether the reciprocal relation just observed is sufficiently simple to admit of formulation and determination. The simplest imaginable reciprocal relation is of course

$$P = \frac{c}{S}, \text{ or } P.\,S = c \qquad (1)$$

where c is some constant number. To test for this relation we need only to multiply the P and S of the different pairs and observe whether or not the products obtained are approximately the same. A few trials show that the relation (1) is not satisfied.

The next simplest reciprocal relation is

$$P = \frac{c}{S^k}, \text{ or } P.\,S^k = c \qquad (2)$$

where both c and k are constant numbers. We could test this relation for any particular k by observing whether $P.\,S^k$ is approximately the same for various pairs of corresponding values of P and S, and by trying various values for k we might ultimately discover the true relation between P and S. However, this is a very laborious process, which may be avoided by writing the assumed relation (2) in its equivalent logarithmic form

$$\log P = \log c - k \log S \qquad (3)$$

and observing that this equation plots into a straight line if log P and log S are used for rectangular coördinates of points. If then the predication-averages and the simple sentence-percentages are connected by some relation of the form (2), the points, representing log P and log S, either value being used for abscissa and the other for ordinate, should lie approximately on a straight line. Moreover, the line being located, the constants c and k may be easily determined, for as is well-known —k is the tangent of the angle which the line makes with the positive direction of the axis along which log S was laid off, and log c is the distance from the intersection of the axis to the point in which the line cuts the other axis.

Let us then collect the eleven pairs of average values of P and S into a table, compute the corresponding values of log P and log S and then plot the eleven corresponding points as shown in figure 1.

			Averages.		Co-ordinates.	
No.	P between	W	P	S	log P	log S
1	1.50 and 2.00	1000	1.86	53	0.270	1.792
2	2.00 and 2.25	9000	2.14	39.1	0.330	1.524
3	2.25 and 2.50	9000	2.34	32.9	0.369	1.517
4	2.50 and 2.75	7000	2.62	25.9	0.418	1.413
5	2.75 and 3.00	5500	2.88	23.2	0.459	1.365
6	3.00 and 3.25	4000	3.10	19.2	0.491	1.283
7	3.25 and 3.50	4000	3.39	15.9	0.530	0.201
8	3.50 and 4.00	7000	3.70	13.4	0.568	1.127
9	4.00 and 4.50	2500	4.17	10.0	0.620	1.000
10	4.50 and 5.00	1500	4.84	8.3	0.685	0.919
11	5.00 and 5.50	1500	5.38	6.7	0.731	0.826
	General Mean		2.96	20.03		

It is at once apparent, from an inspection of the figure, that the points representing the eleven groups of writings lie nearly in one and the same straight line, we therefore infer that the hypothetical relation formulated in (2) is approximately correct. In order to determine the constants which enter into that relation we must actually construct a straight line such that the sum of the deviations[6] of the eleven points from it shall be as small as possible. This is most readily done by moving a stretched thread until it occupies the desired position, that is until the distances from the thread of the points on one side, are balanced by those of the other side.

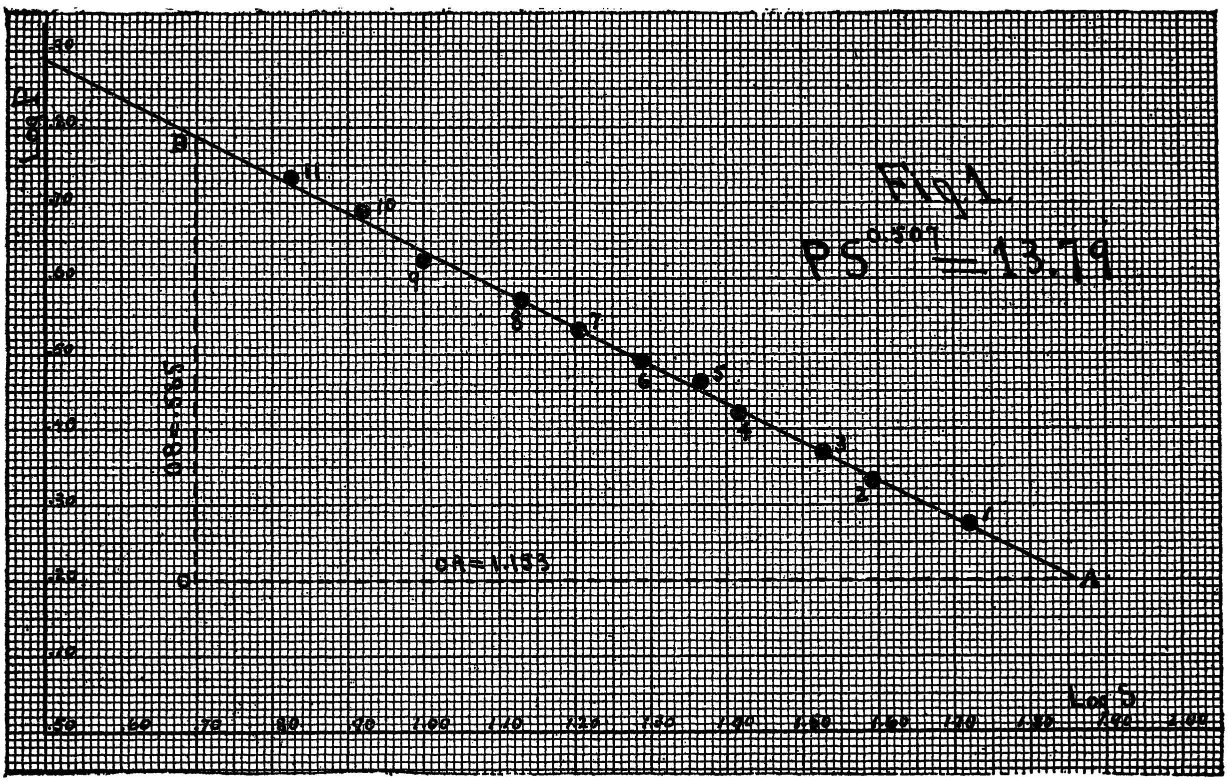
After the line has been drawn the constant k is

[6] Exact treatment according to the laws of probability requires that the sum of the squares of the deviations, rather than the sum of the deviations themselves, shall be a minimum.

obtained from any triangle, as AOB, which has some portion of the line for its hypotenuse, and its other two sides parallel to the co-ordinate axes. Thus from Fig 1:

$$k = \frac{OB}{OA} = \frac{0.585}{1.153} = 0.507.$$

The constant c is obtained from the point where the line intersects the vertical axis. Thus,



$$0.886 = \log c - 0.50\ k,$$
$$\log c = 0.886 + 0.2535 = 1.1395,$$
$$c = 13.79.$$

With these values for k and c, the relation between predication-averages and simple-sentence-percentages becomes

$$\log P = 1.1395 - 0.507 \log S,$$

or

$$P = \frac{13.79}{S^{0.507}}. \qquad (4)$$

Instead of the simple device which has been employed in the determination of the constants in the foregoing empirical formula between P and S, a more rigorous mathematical method (the method of least squares) could have been used. By that method, a rather laborious process leads to two normal equations for the determination of C and k, viz.:

$$52 \log c - 70.046\ k = 23.745$$
$$70.046 \log c - 96.759\ k = 30.767.$$

Solving

$$c = 13.78, \quad k = 0.5068,$$

results which differ but slightly from the values obtained above.

The accuracy with which the empirical formula

$$P = \frac{13.79}{S^{0.507}}$$

represents the true relation between predication-averages and simple-sentence-percentages, may be better realized by comparing results as obtained by actual count, with corresponding results derived by computation from the formula. The following table contains two values of S for a given P, the third column contains the actual,

the fourth the theoretic value. Thus for $P = 2.14$, S as obtained by actual count is 39.1, while computation gives

$$2.14 = \frac{13.79}{S^{0.507}}$$

from which

$$S = \left(\frac{13.79}{2.14}\right)^{1.9724} = 39.6$$

No.	Predication Averages.	Simple-Sentence-Percentages. By Count.	Simple-Sentence-Percentages. By Formula. (4)	W = Weight.	E = Error.	W E².
1	1.86	53	51.9	1	1.1	1.21
2	2.14	39.1	39.6	9	0.5	2.25
3	2.34	32.9	33.1	9	0.2	.36
4	2.62	25.9	26.5	7	0.6	2.52
5	2.88	23.2	22.0	5.5	1.2	7.92
6	3.10	19.2	19.0	4	0.2	.16
7	3.39	15.9	15.9	4	0.0	.00
8	3.70	13.4	13.4	7	0.0	.00
9	4.17	10.0	10.6	2.5	0.6	.90
10	4.84	8.3	7.9	1.5	0.4	.24
11	5.38	6.7	6.4	1.5	0.3	.13

Error of Mean Square, .55
Modulus, - - - .78
Probable Error, - - .38

Those who are accustomed to compare experimental with theoretic values will pronounce the agreement between the numbers in the third and fourth columns of this table exceedingly close, an agreement much closer than is usually obtained from formula embodying so-called physical laws. Technically this accordance is characterized by computing the modulus of the probability curve, which in our case is .78, or the so-called probable error .37 which is the modulus multiplied by .477.

The accuracy indicated by these numbers is moreover corroborated by comparing results calculated from our formula with those obtained by actual count of works not included in our list. For instance, Miss Pound[7] found, from a tabulation of 2665 periods, that Chaucer uses 2.77 predications per period, and 24.8% of simple sentences. Using $S = 24.8$, that one of the two constants most readily determined by count, our formula gives

$$P = \frac{13.79}{(24.8)^{0.507}} = 2.71.$$

Averaging with these 2665 periods the results from the additional 2205 periods from the *Romaunt of the Rose*, also given by Miss Pound, we obtain $S = 22.42$, $P = 2.82$, while the formula gives

$$P = \frac{13.79}{(22.42)^{0.507}} = 2.85.$$

The constants P and S for Macaulay's *History of England* also have been determined with accuracy. By actually counting the simple sentences and finite verbs in the forty thousand periods of the *History*, Professor Sherman found the simple-sentence-percentage for the entire work to be 34.2 and the predication average 2.30. This is precisely the result given by our formula, for

$$P = \frac{13.79}{(34.2)^{0.507}} = 2.30.$$

Formula (4) may be replaced by another which is much simpler and but slightly less accurate. 0.507 is nearly one-half, so that the denominator of the right hand member of the formula may be written

$$S^{0.507} = S^{1/2} = \sqrt{S} \text{ nearly,}$$

that is, without committing much error the k in (2) may be put equal to one-half. If now we draw the line AB in figure 1 so that the tangent of its angle with the horizontal axis is one-half and so that the sum of the squared distances of the points from it is a minimum, the corresponding constant c is found to be 13.5. Formula (4) may then be replaced by the slightly less accurate formula

$$P = \frac{13.5}{\sqrt{S}}, \text{ or } P^2S = 183, \qquad (5)$$

in words :

The average number of predications employed by an English author varies approximately inversely as the square root of the average number of simple sentences per hundred employed by the same author, or, the average number of simple sentences per hundred employed by an English author varies in the long run as the inverse square of the average number of predications per sentence.

The following table compares the counted values of S and the values as calculated by formula (5) :

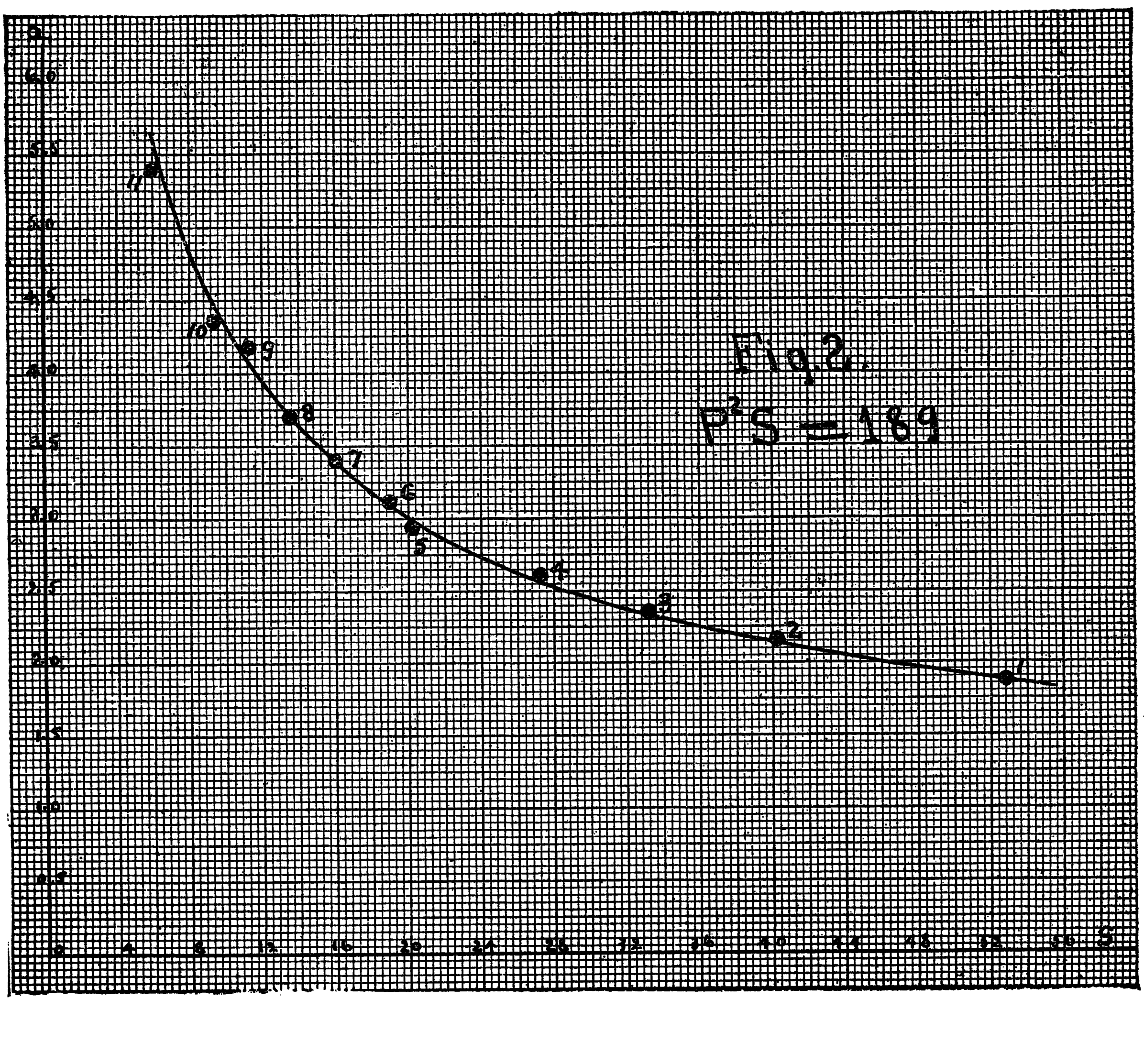
[7] *Modern Language Notes*, Vol. XI, p. 202. Miss Pound gives 2.76 and .024, the discrepancy is due to an error in addition.

No.	P = No. of Predications.	S = Simple-sentence percentages. By Count.	By Formula (5).	W = Weight.	E = Error.	W E².
1	1.86	53.0	52.9	1	.1	0.01
2	2.14	39.1	40.0	9	.9	7.29
3	2.34	32.9	33.4	9	.5	2.25
4	2.62	25.9	26.7	7	.8	4.48
5	2.88	23.2	22.1	5.5	1.1	6.61
6	3.10	19.2	19.0	4	.2	.16
7	3.39	15.9	15.9	4	.0	.00
8	3.70	13.4	13.3	7	.1	.00
9	4.17	10.0	10.5	2.5	.5	.62
10	4.84	8.3	7.8	1.5	.5	.38
11	5.38	6.7	6.3	1.5	.4	.24

Error of Mean Square, .65
Modulus, - - - .91
Probable Error, - - .43

Here the error of the mean square and consequently also the modulus and probable error are but slightly in excess over the corresponding magnitudes for the more exact relation (4). The agreement of the assumed relation (5) with the data collected by counting is perhaps most obvious from an examination of the following graph. The graph represents the inverse square relation $P^2S = 183$, the marked points represent the results obtained by actual count, S and P being used for horizontal and vertical co-ordinates respectively.

It seems, then, that the inverse square relation (5) fits all the observed data as closely as could well be desired, and may therefore be regarded as established until conflicting data are produced.



But the existence of one definite relation suggests the possible existence of others. May not the other sentence-constants be interrelated also, and if so can their laws of interrelation be made manifest and formulated in a simple way? Is it possible to construct a norm or system of norms, and characterize the writings of any given author by their departure from this norm? Unfortunately no data are available to answer these and kindred questions at the present time.

It is hoped that the examples here given and the suggestions made, may receive the attention of students of linguistic science. From the example it should be clear how mathematics itself, the most perfect and powerful instrument of exact thought, may be pressed into the service of linguistic science. The suggestion is that the law of the inverse square connecting simple-sentence-percentages and predication-averages may not be an isolated phenomenon but the first landmark rather of a rich field yet to be explored, pointing the way to an unsuspected branch of philology which under the name of "Literametrics" may become to philology, what "Biometrics" has already become to the biological sciences.

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INTERCHANGE OF SUFFIXES.

-Aster, *-Ignus*, AND *-Icus*.

Meyer-Lübke (*Gram.*, II, page 445) treats briefly the interchange of the Latin suffixes *-aster* and *-ignus*, and the consequent effect upon the Romance words of step-relationship:

> "En regard de l'ital. *figliastro, figliastra, fratellastro, fratellastra*, de l'esp. *padrasto, madrastra*, du fran. *marâtre*, également *par, fill*, . . . figurent l'ital. *patrigno, madrigna*, qui paraissent remonter à *patrigno, matrigna*, refaits à l'époque romaine déjà sur *privignus*; ajoutez-y certaines formes dialectales, p. ex. *fradleń, sorleńa* à Mantoue. C'est encore une autre formation que présentent le napol. *patriye̥, matreye̥*, teram. *patreye̥, matreye̥*, dont le point de départ est dans le grec *μητρυιά*."

This interchange of suffixes has had a wider field of action than Meyer-Lübke has been pleased to show. Suffix *-aster*, in this connection originally compounded with Cl. Lat. *pater, mater* into Vulg. Lat. *patraster, matrastra* (step-father, -mother), soon spread to the forms *filius, filia, frater* (for both genders), and sometimes to *soror* (Prov. *sourrastre*).

Suffix *-ignus* (*-igna*), originally in Cl. Lat. *privignus, privigna* (step-son, -daughter), likewise separated from its stem and helped to form new words of step-kinship (Ital. *patrigno, matrigna*). In several dialects the same stem is found compounded indifferently with either suffix (Venet. *paregno, pareastro*).

Mater $+ >$ O. Fr. marâtre; Ital. matrigna; Span. madrastra; Port. madrasta; Prov. mairastra; Milan. madreg̀na; Venet. mareg̀na; Rhæt. madrastra, madrigna; Namur, maurause; Sicil. marrastra; Roum. mastera.

Pater $+ >$ O. Fr. parâtre; Ital. patrigno; Span. padrastro; Port. padrasto; Cat. padastre; Prov. pairastro; Milan. padreg̀n; Venet. pareg̀no, pareastro; Rhæt. padraster; Sicil. parrastru (f. parrastra; v. mater).

Frater $+ >$ Ital. fratellastro, -a; Mant. fradleń; Sicil. fratastru, -a; Milan. fradellaster; Venet. fradelastro; Parma fradlasch.

Soror $+ >$ Prov. sourrastre; Mant. sorlena; Milan. sorellastra; Sard. sorrastra, sorrestra; Venet. sorelastra; Parma sorlasca.

Filius (a) $+ >$ O. Fr. fillâtre; Ital. figliastro, -a; Span. hijastro, -a; Cat. fillastre; Sicil. figghiastru, -a; Rhæt. figliaster, -astra; Roum. fiastru, -a; Liége fïâs; Prov. filhastre; Sard. fizastru, -a; Milan. fiaster, -astra; Venet. fiastro, -a; Alban. Θieštre̥.